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(D) But the values of $n$ differ, not only Oxford from Greenwich, but zone $+26°$ from zone $+31°$. We turn first to the Greenwich published results to investigate such differences (§§ 16–18).

(E) At Greenwich, for a given exposure, $a$ and $n$ seem to vary together (§ 19). It is suggested that a variable term

$$v(10-\sqrt{d})$$

where $d$ is measured in units of $0''{\cdot}15$ may be added or subtracted to the mean formula, according to the quality of the night.

(F) Reducing to the same value of $n$ the formulæ given in the Greenwich Introduction for different exposures ($40^m$, $6^m$, $3^m$, $20^s$), it is found that the constant $a$ may be written

$$a = c + 2{\cdot}0 \log T$$

where $c$ is independent of the time of exposure T. This corresponds to the following proposition: *When the time of exposure is prolonged in the ratio of five star magnitudes the photographic gain is four magnitudes* (§ 23).

(G) A few points are examined to see whether any explanation of this apparent loss can be found, but without success (§§ 27–33).

(H) Returning to the Oxford results, the plates in several zones are analysed to throw light on the changes in $n$. It is found (§§ 35–43) that $n$ changes with the measurer, and with some alteration at the erection of the new dome; but not with developer, altitude at exposure, R.A. There is also some unexplained change between zones $+30°$ and $+31°$.

(J) Although $n$ does not change very much with $a$ for plates taken under similar conditions, systematic changes in $n$, owing to change of conditions, follow changes in $a$, as in (E) above at Greenwich (§ 35).

(K) The coefficient $2{\cdot}0$ for log T, as in (F) above, is confirmed by such evidence as the scanty material for studying long exposures at Oxford offers (§§ 44–48).

*University Observatory, Oxford:*
1905 *May* 27.

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## *Determinations of Stellar Parallax from Photographs made at the Cambridge Observatory. Introductory Paper.* By Arthur R. Hinks, M.A., and Henry Norris Russell, Ph.D.

§ 1. Our purpose in the present paper is to give a general account of the investigations of stellar parallax undertaken at Cambridge with the Sheepshanks Equatorial in 1903. In that

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year we planned a considerable scheme, which was put into operation forthwith owing to the appointment of one of us (H. N. R.) as a research assistant to the Carnegie Institution, and of which the first results are now available. The present moment seems therefore to be appropriate for an introductory account of the work. Two years' experience of the scheme in operation has shown us that it works well, and that the results come up to the standard of internal agreement which we set up. But since we hope that the work will be continued for some years, we should value present criticisms of the plan as matured by us, so that they may not come too late to enable us to avail ourselves of them.

§ 2. In making our plans we kept two main objects in view :

*a.* To secure the most advantageous relation between the amount of labour to be expended and the probable accuracy of the results to be achieved.

*b.* To eliminate at any cost all known sources of systematic error ;

And these led to the adoption of certain rules for the work, which may be briefly discussed as follows :

After careful consideration we decided not to adopt Professor Kapteyn's plan of accumulating exposures at successive epochs upon the same plate. It is well known that there are grave practical difficulties in carrying out this plan, which requires extreme care in the identification and preservation of undeveloped plates, great accuracy in adjusting the plate upon the telescope at each epoch, and, above all, reasonable certainty that the result of each separate exposure shall be successful, since the failure of one destroys the value of others as well. Further, we did not intend to limit the work on any object to three parallax epochs, but proposed to add a fourth and a fifth epoch for many stars, and to keep a few stars upon our working list for several years to serve as a control of the whole work. Again, considerations of another kind made it imperative to adopt the rule that all plates should be taken nearly on the meridian, which is a very severe restriction in itself in an uncertain climate, and renders it doubly undesirable that we should be hampered by any time-consuming processes. Finally, we did not want to be compelled to work for a whole year before any plates could be measured. We therefore decided :

I. *To take separate plates at each epoch and develope them at once* : Each plate has four exposures separated by 0·5 mm. in declination, and is impressed with a standard réseau. We intended to take two or three such plates at each epoch, but occasionally found it impossible to get more than one.

§ 3. Many of the stars which promised to give most interesting results were too bright to give measurable images on a plate exposed for three minutes, which is usually the minimum required to bring up enough comparison stars. We decided therefore to

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use a special form of colour screen. Experiments showed that if one of the ordinary sensitive plates of patent plate glass was cleared, and a small patch of the gelatine film stained with yellow dye, a bright star photographed through this screen, held in the plate carrier almost in contact with the plate, could be diminished any desired number of magnitudes, and that definition was not sensibly affected anywhere in the field. It is easily shown that the effect of the parallel screen is to alter the focal setting by about one third of the thickness of the screen, while the scale value is unaffected. If the screen is 1·5 mm. thick and separated from the plate by a space of 0·5 mm., a deviation of the normal to the surface of half a minute of arc at the front, or one and a half minutes of arc at the back surface, produces a displacement in the image of 0·0001 mm. It follows that no great accuracy is required in figuring the surface of the screen, and it is probable that one could always find a piece of glass sufficiently good among one's spoiled plates.

The screen which we have used hitherto was made of worked glass by Messrs. Sanger Shepherd & Co., to whom we are much indebted for the interest they have taken in the experiment and the care which they have given to the work. A thin film of gelatine was coated on to the surface and dyed a deep orange; it was then cut down to a patch 3 mm. square. This screen diminished the light of a star about six magnitudes. It was usually quite easy to set for and pick up the selected finding star so that the bright star fell well within the colour patch. When it was desired to photograph a star such as $\mu$ *Herculis* inside the patch with its ninth-magnitude companion about 30″ distant outside, the back of the plate carrier was taken off and the instrument set with the screen in place, the stars being viewed with a low-power eyepiece. When we were satisfied that this colour-screen method gave results which looked good, we added a number of bright stars to the programme and adopted the second rule:

II. *All stars brighter than* $6^{\text{m}}\cdot 0$ *are to be photographed with a colour screen:* The only serious difficulty with these screens is that they are not permanent. We heard from Messrs. Sanger Shepherd that they had some difficulty in getting the small gelatine patch to adhere to the worked glass surface. They finally succeeded so well that after rather more than twelve months' use the patch, contracting, pulled off the face of the glass. Our series for bright stars were thus interrupted for the time. We realise that it is necessary to devise a form of screen which is permanent, not easily scratched, and which can be cleaned, and experiments are now in progress towards that end.

There is one objection which may be brought against the use of an orange screen to cut down a star's light: that the effective wave-length of the light from the bright star is not the same as that of the light from the comparison stars, and that conse-

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quently atmospheric dispersion may produce an exaggerated effect. On the meridian this acts only in the $y$ coordinate, which we do not generally use (see later). It should be remarked that the light which, after passing through the orange screen, forms the image of the star is not necessarily of greater effective wave-length than usual, since the orange dye may let through violet light. Should we adopt the orange dye for the final form of our screen, its absorption spectrum must be examined photographically.

§ 4. Let us now consider the various systematic errors which may be found in the plates, beginning with those of a permanent or semi-permanent kind.

The most serious are those included in the category of "hour-angle error," of which the two principal causes may be : (1) optical distortion varying with the hour-angle, especially when, as at Cambridge, a mirror forms part of the optical train ; (2) atmospheric dispersion. We realised from the outset that the way to ensure freedom from these errors was to work at a definite hour-angle for each star ; the only question was, Should we work always on the meridian, or choose in some cases an hour-circle not very far from it ? If we chose the meridian, and measured only the $x$ coordinates, any effect of atmospheric dispersion must be eliminated ; but we should be sacrificing a good deal of parallax factor, and consequently of the weight of our determination.

It is not necessary to reproduce here the tables which were constructed to show what was the maximum parallactic displacement in $x$ which could be obtained for any star, on the condition that it was photographed upon the meridian at a time when the Sun was at least 10° below the horizon. The whole available displacement in $x$ is $1{\cdot}57\pi$ for a star in $0^h$, rises to $1{\cdot}93\pi$ for a star in $6^h$, falls to $1{\cdot}45\pi$ for a star in $16^h$, and is then nearly constant as far as $22^h$ R.A.

The parallax factors for the limiting morning and evening observations under these conditions are usually unequal, and the total displacement might be somewhat increased by observing off the meridian in a particular hour-angle for each star. But there is a peculiar inconvenience about this procedure. The most favourable dates for observation of all stars between $15^h$ and $21^h$ R.A. are crowded into a few weeks ; and, what is worse, all these stars must be observed between $17^h\ 20^m$ and $18^h\ 40^m$ sidereal time. By departing from the meridian to gain a slight formal advantage in parallax factor we make a hopeless block in the observing programme. We have therefore adopted the simple working rule :

III. *All photographs must be taken within half an hour of the meridian :* It is very convenient to make the working list in the form of a card catalogue. Each star has a card on which the parallactic ellipse is drawn from the tables given by Sir David Gill (*Annals of the Cape Observatory*, vol. viii.). On the ellipse are

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marked the places corresponding to the dates up to which evening observations and from which morning observations are possible. A glance at the card shows whether circumstances are favourable or unfavourable; whether the evening observations should be put off to the last moment, or may be made with equal advantage any time in the preceding month; and whether the morning observations must be got immediately after the earliest possible date, or may be delayed without damage. The conditions vary so much from star to star, especially in a latitude like that of Cambridge, which is really too high for convenient parallax work, that to have the diagrams always in sight is really necessary. They are made complete by a tracing from the B.D. chart to identify faint stars, and by the necessary miscellaneous instructions.

§ 5. Errors of the réseau, including "projection errors," scarcely enter into the parallax equations if reasonable care is taken in centering the plate: they affect only the star places.

An error of a semi-permanent kind is tilt of the plate, which displaces the centre of the plate with respect to the edges. It is particularly necessary to guard against such an error accumulating.

§ 6. Perhaps the most important error which is likely to affect all the exposures on one plate systematically, but to vary from plate to plate, is "guiding error." If the clock is not driving correctly, it is probably going pretty regularly either fast or slow, and the stars on the plate are continually trailing a little in one direction and being brought back: under these conditions a bright star image is displaced with reference to a faint by an amount which becomes quite sensible before the distortion of the disc is apparent on inspection. A good electric control will correct errors as soon as they amount to two or three tenths of a second of arc, and possibly the best visual guiding may do the same. The automatic control has this advantage, that one can set the clock regulator so that the accelerating and retarding trains come into operation with nearly equal frequency, which eliminates guiding error, properly so called. A slight continuous trail in one direction has little or no effect on the relative places of the images.

Another "plate error" is local distortion of the gelatine film, too local to be eliminated by the use of the réseau. Discordances appear from time to time which may be attributed with some confidence to this source. The remedy is to separate the different exposures well, and not to take too many on one plate.

§ 7. The plates are measured upon the Cambridge measuring machine (described in *Monthly Notices*, 1901, vol. lxi. p. 441), which has been found to be extremely convenient, accurate, and satisfactory. It has been found to be free from sensible errors of screws, scales, or optical distortion, with the exception of one very small term, which is rigorously eliminated when the plate is measured in two opposite orientations. The accidental error of

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setting on a star-image appears to be very small, so that it does not pay to make many settings on a single image. We usually make two—more if the first two are discordant.

It is worth remarking in this connection that bad seeing does not usually appear to have much influence on the accuracy of the measures of a plate, though it may make the images diffuse.

At first all images were measured in two opposite orientations. It occurred to us later that if the error of measurement depending upon orientation was really systematic for images of a given intensity and appearance, it should be eliminated in the mean of the measures of several images of the same star by measuring half of them in the direct position only and the other half in the reversed.

Examination of the measures of about thirty plates showed that this was the case, and that very little accuracy would have been lost if the labour of measurement had thus been reduced by one half. We therefore adopted the rule :

IV. *Measure only two of the four exposures on a plate in the direct orientation, and the other two in the reversed:* § 8. It is possible to economise measurement still more. From the diagrams of our card-catalogue it appears that the available parallactic displacement for observations on the meridian is rarely more than half as great in the $y$ coordinate (declination) as in the $x$, so that for parallax purposes the $x$'s have on the average more than four times as much weight as the $y$'s.

It is therefore desirable to confine exact measurements to the $x$'s alone. To be sure we need approximate values of the $y$'s in the reduction of the plates, but these can be obtained from rough measures of a single plate—in fact, of a single exposure—in perhaps $\frac{1}{20}$ of the time that it would take to measure the $y$'s completely.

So we made the rule :

V. *Measure the* x's *accurately on all plates, but the* y's *approximately on one plate only :* This, again, saves half the work of measuring, and reduces it to a moderate proportion of the total work.

If the $y$'s have weight enough to make it worth while to discuss them at all, this may be very easily done after the $x$'s are finished, as will appear later.

§ 9. We have now to reduce our measures to a common standard system. Standard coordinates computed from catalogue places of stars are not well suited to our purpose. There are usually not enough catalogue stars on our plates ; the errors of their tabular places are much larger than those of the photographs ; and the necessary calculations take a good deal of time. The photographs themselves are free from all these objections. But a standard derived from them may differ slightly in scale value and orientation from the assumed values of these constants which we use in computing the parallax factors. These differ-

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ences, however, are in practice so small that they cannot sensibly alter the deduced value of the parallax.

So our procedure is :

VI. *Choose any plate, or the mean of any number of plates, as a standard, and reduce the others to this :* Since all the necessary corrections for any given plate are linear functions of the coordinates it follows that the difference of the measured coordinates of the same star on two plates (barring accidental errors and proper motion) is a linear function of its coordinates on either one of the plates, or on any other plate of the same field, or even of the $x$ of one plate and the $y$ of another.

Each of our comparison stars (which as a first approximation we must assume to have no sensible parallax or proper motion) gives us then an equation of condition of the usual form

$$x-\xi=a\xi+b\eta+c$$

where $x$, $y$ are the coordinates on the plate, and $\xi$, $\eta$ the standard coordinates.

These equations might be discussed by least squares to find the plate constants $a$, $b$, $c$. But there is an approximate method, first proposed by Dyson, which has been found in practice to give about as good results with much less work. The following are some results of an investigation by one of us (H. N. R.) which will appear later.

(1) The least-square and approximate methods give identical values of the reduction to standard for a star situated at the centre of gravity of the comparison stars (considered as a system of equal particles in a plane). For other points the two methods give slightly different values, depending upon the differences of the constants $a$ and $b$.

(2) When the comparison stars are distributed with tolerable symmetry in the four quarters of the plate, the values of $a$ and $b$ obtained by the approximate method differ from the least-square values by less than the probable errors of the latter.

(3) The weight of the reduction to standard determined by least squares is greatest for the centre of gravity, and falls off with increasing rapidity as we move away from this point in any direction. At the average (mean-square) distance of the comparison stars from the centre the weight is $\frac{1}{3}$ of its maximum value. If there are $n$ comparison stars the maximum weight of the reduction is $n$ times that of one equation of condition.

It follows from the above that the comparison stars should be so chosen that ($a$) their centre of gravity falls as near as possible to the parallax star, and ($b$) they are as evenly distributed as possible among the four quarters of the plate. If these conditions are fairly well satisfied, the approximate method of reduction may be used without loss of accuracy. Our experience shows that this can almost always be done in practice.

It should be remembered that in our equations of condition

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we have expressed the correction necessary to reduce a plate to standard as a function of the standard coordinates. Consequently when our "parallax star" has a large proper motion, we must correct the standard coordinates of this star for this motion before using them to compute the quantity $a\xi+b\eta+c$. This correction is only sensible for a few very rapidly moving stars.

§ 10. If accidental errors alone had to be considered, it would pay us to use very few comparison stars, and to spend the time saved in measurement upon taking more plates. The error of a *reduced* coordinate of our parallax star consists of two parts : ($a$) the error of its own measured coordinate, and ($b$) that of the calculated correction to reduce it to standard. Only the latter part, which is the smaller of the two, can be diminished by using more comparison stars. Calculation on this basis shows that it would pay us best to use only four or five comparison stars, and take more plates, even if it took us twice as long to take a plate as to measure it.

But to take more plates, with our restrictions and climate, is not always possible, and there is an obvious objection to the use of so few comparison stars, for one of them may have a considerable proper motion or parallax much greater than the errors of observation.

This will alter the absolute term of one of our equations of condition by an amount compared with which the errors of the other equations may be neglected. If we had only three comparison stars, it would still be possible to find values of $a$, $b$, $c$ which would exactly satisfy the three equations of condition. If we had four, consideration of a typical case shows that both the least-square and approximate solution give almost equal residuals for the four stars—two positive and two negative—so that we cannot pick out the bad one. Something of the same sort happens whenever the bad star is alone in the quarter of the plate in which it lies. To enable us to pick out possible cases of large proper motion or parallax among our comparison stars we must have at least two of them in each quarter of the plate.

In the great majority of fields it is possible to find eight measurable stars, such that their centre of gravity lies within a few minutes of arc of the parallax star, while there are two of them in each quarter of the plate.

It often helps us to satisfy the last condition if the lines dividing the plate into quarters (*i.e.* those separating the stars which are combined into groups in the approximate method of reduction) are inclined to the axes of coordinates.

§ 11. When all the plates of a field have been reduced, the residuals for the parallax star are converted into seconds of arc, reduced to a common epoch with the tabular proper motion of the star, and discussed by least squares in the ordinary fashion, the unknowns being corrections to the star's assumed $x$ coordinate and proper motion, and its parallax. It is not worth while to

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discuss the residuals for the comparison stars by least squares, because, as we have just seen, any parallax or proper motion in one of them will produce systematic changes in the residuals for all the others, so that the results for the different stars are not independent. Approximate values of the proper motions and parallaxes may, however, be very quickly obtained from the means of the residuals for each parallactic epoch. If any comparison star has a large parallax or proper motion the fact will appear by inspection of its residuals. It should then be abandoned as a comparison star, and put on the list of "parallax stars," and the plates be reduced anew with the remaining comparison stars. It is also worth while to measure approximately the *y*'s on one plate of the last epoch, and reduced this to our standard, so that any large proper motion in declination may be detected.

In this way we may assure ourselves that none of our comparison stars has a large parallax. If we assume that the relative parallaxes and proper motions of these stars are really insensible, and that the values we have calculated for them are entirely due to accidental errors, we obtain a superior limit to the probable error of a parallax or proper motion derived from our plates. If the probable errors so obtained agree with those found from the least-square solution for the "parallax star" we may be satisfied that our comparison stars are really remote.

We may then pick out three of them, so that their centre of gravity falls near the "parallax star," measure accurately the *y*'s for these four stars, reduce them to standard, and get from them a new determination of the parallax. This involves much less work than the discussion of the *x*'s, for the reductions may be made very short. We are thus able to utilise the *y*'s without too much work in proportion to their weight.

§ 12. Our solutions give us the difference between the parallax of our principal star and the mean of those of the comparison stars. We know the magnitudes of the latter and superior limits for their proper motions. Now Professor Kapteyn has shown that the mean parallax of a group of stars of known proper motion and magnitude can be predicted with considerable accuracy, so that for eight stars it is decidedly improbable that the actual mean will differ from the computed one by half the amount of the latter. For our comparison stars his formulæ give a mean parallax less than $0''\cdot01$.

As we have already safeguarded ourselves against the exceptional case when one of our comparison stars has a large parallax, we may be satisfied that the uncertainty of their mean parallax will be small, and we may therefore pass from the relative to the absolute parallax of our principal star with some confidence when we desire to use the result for statistical purposes.

§ 13. There remain for consideration the principles that have guided us in forming our first working list.

It has been shown clearly by Kapteyn and Newcomb that the average parallax of stars is so small that if a large list of

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stars is selected at random and observed, the spurious parallaxes will be far more numerous than the real parallaxes in the list of results: in other words, we are not yet in a position to attack the problem of parallaxes in general. While methods are still in an unsettled state, and while there is little evidence as to the real probable error of a parallax derived by photography, we shall do well to confine our attention to stars of two carefully selected classes.

A. Stars for which any information as to parallax, even if it be only a superior limit, is valuable—visual binaries, where the parallax gives the mass; variable stars, where the parallax gives the real range of light variation in terms of the light of the Sun; pairs of stars with common proper motion, where the parallax gives the size of the system; star clusters; and nebulæ.

B. Classes of stars which are likely to have larger parallax than the stars in general—bright stars and stars of large proper motion, especially the latter.

There will naturally be a wide difference of opinion as to the objects to be included under the first head; the second is in some respects easier to settle. We have tried to include the most promising stars of types I. and III., for which information is scanty. We have also included a number of stars of both classes which have been investigated elsewhere with discrepant results.

The observation of a great part of the objects in this first list is well advanced, and we hope to be able to publish first results for the whole within the next year or two. Our experience up to the present seems to show that one observer who can give his whole energy to the work may have with advantage about forty stars on his working list, of which he will miss a few at one epoch or another owing to spells of bad weather. In this country he will not accumulate very many more plates than he can measure to reduce if he imposes on himself the stringent rule of meridian observation which we have considered essential and adopts the simplified programme of measurement and reduction which we have used.

We should like to say in conclusion that we think it very desirable that those astronomers who are undertaking determinations of stellar parallax should follow the example of the line-of-sight spectroscopists and observe regularly a few stars in common. Only by some such informal co-operation does it seem possible to test what is the absolute accuracy of the work. We should therefore welcome suggestions for additions to our working list as well as criticism on the methods we have adopted.

*First Working List for Stellar Parallax. Cambridge Observatory.*

| Name. | Position 1900·0. α | δ | Mag. | Sp. Type D.C. | P.M. on Great Circle. | Notes. |
|---|---|---|---|---|---|---|
| | h m | ° | | | ′ | ″ |
| β Cassiopeiæ ... | 0 3·8 | +58 36 | 2·42 | F. | 0·55 | 0″·16 Pritchard; 0″·10 Flint |
| Groombridge 34 ... | 0 12·6 | +43 27 | 7·9 | | 2·80 | 0·29 Auwers; 0·31 Flint. |
| η Cassiopeiæ ... | 0 42·9 | +57 18 | 3·64 | F. | 1·20 | Binary; 7ᵐ comp. dist. 5′ (1900). 0·18 Peter; 0·44 Davis; 0·34 Flint. |
| Mayer 20 ... | 0 43·1 | + 4 46 | 5·7 | H.? | 1·37 | 0·16 and 0·12 Flint. |
| μ Cassiopeiæ ... | 1 1·6 | +54 26 | 5·21 | H. | 3·75 | 0·13 Peter; 0·24 Bauer; 0·28 Jacoby; 0·07 Flint. |
| θ Cassiopeiæ ... | 1 5·0 | +54 37 | 5 | A. | 0·22 | 0·23 Jacoby. In same field with μ. |
| o Ceti ... ... | 2 14·3 | − 3 26 | Var. | M. | 0·24 | |
| ρ Persei ... ... | 2 58·8 | +38 27 | Var. | M. | 0·18 | Irregularly periodic. |
| β Persei ... ... | 3 1·7 | +40 34 | Var. | A. | 0·03 | Sp. binary. 0·07 Chandler; 0·04 Chase. |
| Lalande 6888, 9 ... | 3 40·2 | +41 9 | 9; 9·5 | | 1·38 | Double; dist. 9″; −0·14 Flint. |
| λ Tauri ... ... | 3 55·1 | +12 12 | Var. | B. | 0·02 | Algol var. 3·4 to 4·2; sp. binary, both comp. bright. |
| Lalande 7443 ... | 3 56·5 | +35 2 | 8·5 | | 2·19 | −0·02 Flint. |
| „ 9012 ... | 4 44·4 | +45 41 | 7·5 | A. | 0·68 | |
| η Geminorum ... | 6 8·8 | +22 32 | Var. | M. | 0·07 | Var. 3·2 to 4·2. Vis. and sp. binary. |
| ζ Geminorum ... | 6 58·2 | +20 43 | Var. | H.? | 0·02 | Var. 3·7 to 4·5. Sp. binary; probably triple. |
| κ Geminorum ... | 7 28·2 | +32 6 | 1·56 | A. | 0·21 | Binary; both comp. sp. binaries. +0·20 Johnson; −0·17 Flint. |
| Hydræ ... ... | 8 41·5 | + 6 47 | 3·5 | F. | 0·21 | Vis. and spect. binary. |
| Ursæ Maj. ... | 8 52·4 | +48 56 | 3·17 | A. | 0·50 | 0·13 Peters; 0·11 Flint. |
| o Ursæ Maj. ... | 8 54·2 | +42 11 | 4·19 | F. | 0·51 | 0·20 Belopolsky; −0·07 Flint. Common P.M. with ι Ursæ. |
| Groombridge 1646 | 10 21·9 | +49 19 | 6·5 | A.? | 0·84 | 0·11 Kapteyn. |
| Lalande 21185 ... | 10 51·9 | +36 38 | 6·8 | | 4·75 | 0·50 Winnecke; 0·43 Kapteyn; 0·37 Flint. |
| „ 21258 ... | 11 0·5 | +44 2 | 8·5 | | 4·40 | 0·26 Auwers; 0·26 Krüger; 0·17 Kapteyn; 0·37 Flint. |
| Ursæ Maj. ... | 11 12·9 | +32 6 | 4; 5 | G. | 0·74 | Vis. binary; brighter comp. sp. binary. |
| L. Oe. 11677 ... | 11 14·8 | +66 23 | 9·0 | | 3·04 | 0·25 Geelmuyden; 0·19 Bergstrand. Other stars near suspected of parallax. |

| Name. | Position 1900·0. | | Mag. | Sp. Type D.O. | P.M. on Great Circle. | Notes. |
|---|---|---|---|---|---|---|
| | α | δ | | | | |
| | h m | ° ′ | | | ″ | ″ ″ |
| $83_1$ Leonis .. | 11 21·7 | + 3 33 | 6·5 | I. | 0·75 | |
| $83_2$ | | | 7 | | 0·68 | |
| β Leonis ... ... | 11 44·0 | + 15 8 | 2·07 | A. | 0·54 | 0·05 and 0·01 Pritchard. |
| Groombridge 1830 | 11 47·2 | + 38 26 | 6·5 | A.? | 7·05 | 0·18 Schlüter; 0·16 Kapteyn −0·01 Flint. |
| Lalande 22901 ... | 12 7·8 | + 10 36 | 7·5 | | 0·44 | These three stars seem t form a group. The P.M. i almost entirely in decl southward. |
| „ 22908 ... | 12 8·2 | + 11 24 | 7·5 | | 0·59 | |
| „ 22914 ... | 12 8·4 | + 10 36 | 7 | | 0·30 | |
| γ Virginis . | 12 36·6 | − 0 54 | 3·0; 3·2 | F. | 0·58 | Binary. Sp. Type I (McClean). |
| δ Virginis ... | 12 50·6 | + 3 56 | 3 | M. | 0·51 | |
| Lalande 25334 ... | 13 34·7 | + 11 15 | 5·6 | A. | | 0·25 Flint. |
| A. G. Berlin A. 4999 | 13 40·2 | + 18 20 | 9·2 | | 2·0 | |
| Lalande 25372 ... | 13 40·7 | + 15 20 | 8·5 | | 2·32 | 0·43 Flint. |
| ξ Boötis ... ... | 14 46·8 | + 19 31 | 4·5; 6·5 | G. | 0·16 | Binary. |
| A. Oe. 14318 ... | 15 4·7 | − 15 59 | 9·3 | | 3·74 | A pair with a remarkabl common P.M. |
| „ 14320 ... | 15 4·7 | − 15 54 | 9·2 | | 3·74 | |
| Lalande 27742 | 15 8·3 | + 19 39 | 7·5 | | 0·67 | A pair with proper motio essentially the same. |
| „ 27743 | Δα + $0^s$·31 | Δδ + 23″·3 | 8·0 | | 0·62 | |
| OΣ 298 ... ... | 15 32·4 | + 40 9 | 7; 7·4 | | 0·50 | Visual binary. |
| Weisse$_2$ 720 ... | 15 32·5 | + 40 8 | 7 | | 0·50 | Follows proceeding pai $5\frac{1}{2}^s$, 1′ 43″ N. The tw pairs have common P.M. |
| Lalande 29381 ... | 16 1·5 | + 39 26 | 7 | | 0·56 | In the same field, but P.M in different directions. |
| „ 29439 ... | 16 2·9 | + 38 55 | 8·5 | | 0·60 | |
| ζ Herculis ... | 16 37·6 | + 31 47 | 3 | G. | 0·61 | Binary, 3 and 6·5; masse equal. 0·15 Lewis (spectroscopic). |
| η Herculis ... | 16 39·5 | + 39 7 | 3·69 | K.? | 0·08 | 0·40 Belopolsky; 0·15 Flint |
| W. B. XVII. 322 . | 17 20·8 | + 2 14 | 8·0 | | 1·36 | 0·17 Flint. |
| $\mu_1$ Herculis ... | 17 42·6 | + 27 47 | 4·0 | I.? | 0·81 | A faint companion with common P.M. is a binary 9·4 and 10. |
| Σ 2398 ... ... | 18 41·7 | + 59 29 | 8·2 | | 2·27 | Double; 17″; common P.M. 0·35 Lamp; 0·32 Flint. |
| Munich I. 18180... | 18 53·1 | + 5 48 | 9 | | 1·26 | |
| 6 Cygni ... ... | 19 9·5 | + 49 40 | 6·6 | H. | 0·64 | Double; 10″. 0·48 Ball −0·02 Hall. |
| B.D. + 30° 3639... | 19 30·9 | + 30 18 | 9 | | | Wolf-Rayet star with hydrogen atmosphere 5″ i diameter. |
| Lalande 37647 ... | 19 41·8 | + 33 22 | 8·5 | | 0·47 | Double. |
| „ 37686 ... | 19 42·6 | + 33 34 | 5·5 | | 0·47 | Common P.M. with last. |

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| Name. | Position 1900·0. | | Mag. | Sp. Type D.C. | P.M. on Great Circle | Notes. |
|---|---|---|---|---|---|---|
| | α | δ | | | | |
| | h m | ° ′ | | | ″ | |
| 61 Cygni ... ... | 21 2·4 | +38 15 | 5·11 | H. | 5·16 | 0″·36 Wilsing, with suspected periodic motion of 61₁; Davis finds parallax of two stars sensibly different. |
| Equulei... ... | 21 9·6 | + 9 37 | 4·5 | F. | 0·30 | Short period binary. 0·02 Flint; 0·02 Leavenworth; 0·07 Hussey (spectroscopic). Necessary to take plates through period of six years to eliminate effect of close binary. |
| Cygni ... ... | 21 10·8 | +37 36 | 4; 10 | F. | 0·48 | Binary. 0·08 Beloposky. |
| Lalande 43492 ... | 22 12·3 | +12 24 | 7 | A.? | 0·83 | |
| Kr. 60 ... ... | 22 24·5 | +57 12 | 9; 11 | | 0·95 | Binary. 3″. |
| Cephei ... ... | 22 25·5 | +57 54 | Var. | F.? | 0·01 | Sp. binary. |
| Pegasi ... ... | 22 58·9 | +27 32 | Var. | M.? | 0·22 | Irregular. |
| Lalande 45755 ... | 23 16·8 | +48 33 | 7·5 | A. | 0·68 | |
| Andromedæ ... | 23 32·7 | +45 55 | 4 | K. | 0·45 | Sp. binary. |
| Lalande 46650 ... | 23 44·0 | + 1 52 | 8·7 | | 1·4 | 0·23 Flint. |

*Cambridge Observatory:*
1905 *June* 2.

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## *The Parallax of Lalande* 21185 *and γ Virginis from Photographs taken at the Cambridge Observatory.* By Henry Norris Russell, Ph.D.

§ 1. The work upon which the writer has been engaged for the past two years as a research assistant of the Carnegie Institution has now progressed far enough to permit the publication of its first results. An outline of the methods employed, with the reasons which led to their adoption, is given in the preceding paper. The present communication deals with the numerical data obtained for the first two stars whose discussion has been completed.

§ 2. *Lalande* 21185.—

R.A. $10^{h}\ 57^{m}{\cdot}9$, Dec. 36° 37′ N. (1900·0), Mag. 7·3, P.M. 4″·77.

Previous investigations have shown that this is one of the nearest stars in the northern hemisphere, but they differ among themselves sufficiently to justify a fresh determination of its parallax.

The present discussion is based upon eight plates taken with